DIVERSITY AND ABUNDANCE OF INSECT POLLINATORS AND THEIR EFFECT ON YIELD AND QUALITY OF COWPEA AND CUCUMBER IN MAKUENI, KENYA

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Abstract

Inadequate pollination is one of the key limitations in crop yield and quality of key vegetable crops. Cowpea and cucumber are crops of economic importance in Makueni county-Kenya. A study of insect pollinators and their role on yield and quality of cowpea and cucumber was conducted during the short and long rain seasons in 2017 and 2018 respectively in Kikome, Makueni- Eastern Kenya. The experiment was laid out as a split plot in a randomized complete block design with three replications and involved bagged and unbagged treatments. Eight insect pollinator species (4 orders, 7 families) were recorded on cowpea flowers and 10 species (4 orders, 8 families) on cucumber flowers. In cowpea, the abundance of Hymenoptera was maximum (5 species) while the orders Coleoptera, Lepidoptera and Hemiptera were each represented by a single insect pollinator. *Apis mellifera* was the most abundant of all insect pollinators observed (96.58% and 52.44% during the short and long rain seasons respectively). The peak foraging activity of *Apis mellifera* was recorded between 8:00am to 9:00am and 7:00am-8:00am during the short and long rain seasons respectively. In cucumber, abundance of Hemiptera was maximum (5 species) followed by Hymenoptera (3 species) and Lepidoptera (2 species), while Coleoptera and Diptera were each represented by a single species. *Apis mellifera* was the most abundant of all insect pollinators observed (96.50% and 64. 29% during the short and long rain seasons respectively). The peak foraging activity of *Apis mellifera* was recorded between 8:00am to 9:00am and 9:00am -10:00am during the short and long rain seasons respectively. Unbagged treatments had significantly higher yield and germination percentage than the bagged treatments in both test crops (p<0.05). This study highlights the importance of insect pollination as an additional input in enhancing the yield and quality of cowpea and cucumber in Makueni-Eastern Kenya.

Keywords: Insect pollinators, Diversity, Cowpea, Cucumber, Insect, Yield, Makueni

Introduction

Cowpea (*Vigna unguiculata* L.) belongs to the family Fabaceae. It is drought tolerant and grows well at an optimum temperature of 30°C and 300mm of rainfall per year making it the plant of choice in arid and semi-arid regions of Eastern Kenya. It is rich in proteins (23-25%), starch (50-67%) and vitamin B (Ntoukam *et al*., 1993) hence a highly nutritious crop. Cucumber (*Cucumis sativus* L.) belongs to the family Cucurbitaceae. It is a warm-season crop that does well in temperature ranging from 18ºC - 30 ºC, elevation of 1700m above sea level and optimum of 800mm of rainfall hence supplemental irrigation necessary for consistent moisture availability (Pedrini, 2018). The crop is usually monoecious, both male and female flowers occurring on the same plant. Male flowers are found in clusters on a slender stem and housing three stamens. In contrast, female flowers occur singly with a large ovary at the base. Cucumber flowers are usually yellow, with wrinkled petals. Both male and female produce large volumes of nectar attracting a variety of insect pollinators. Stigma is receptive during the day, but more receptive early in the morning (Collins, 2007). Fresh cucumbers are reliable sources of dietary fiber, vitamin C, thiamine, niacin, iron, calcium, and phosphorous (Gopalan *et al*., 1982).

Cowpea is both self and cross-pollinating producing nectar that attracts variety of insects such as *Apis mellifera*, *Megachile sp*, *Melecta sp, Brussel sp, Brausepis sp, Melecta sp, Amegilla sp, Lasioglossum sp, Ceratina sp, Xylocopa calens, Lipotriches sp, Xylocopa imitator*, moths, butterflies (Lepidoptera), wasps (Hymenoptera), and thrips (Thysanura) (Hordzi, 2011). Its flowers open between 6:00am-6:30 am and closes between 11:30 am -12:00 pm (Ige *et al*., 2011). Insect pollination contributes to higher fruit set, heavy pods, larger pod length, healthy seeds, and higher number and weight of seeds per pod (Chiari *et al*., 2005: Fohouo *et al*., 2009). Cucumber, like other cucurbits, is cross-pollinated resulting in maximum fruit set with well-shaped fruits, while poor pollination results in deformed fruits. Additionally, insect pollination results in fruits of higher weight, large size, more number of seeds per fruit, higher seed weight and uniform maturity (Thakur, 2007).

Information about cowpea and cucumber pollination and their pollinators is scanty in Makueni-Eastern Kenya. Lack of pollination can be a limiting factor in high fruit or seed yield and quality. Limited knowledge of pollinator-plant interaction in the ASALS has exposed pollinators to diseases, pests, parasites, predator, and pesticides use. Despite the economic importance of cowpea, seed production is still limited due to poor crop husbandry and insufficient pollination. Pollen grains of cucumber are heavy and sticky hence their transfer from anthers to stigma is limited in the absence of insect pollinators (Sarwar *et al*., 2008). Research has however shown that cucumber and other curcubits are able to set fruits to a smaller extent without insect pollination attributed to chances of wind pollination leading to considerably lower yield than cross-pollinated crops (Inam *et al*., 2015). In addition, pollination of crops can take place by chance if assisted by man or nectar thieves (Kasina *et al*., 2007). Keeping in view the pollination requirements of the two crops, the present investigations were done to study various insect pollinators, their abundance in selected time of the day, and their impact on the yield and quality of the respective test crops.

Materials and Methods

Study Site

The study was conducted from November 2017 to March 2018 (short rain season) and April 2018 to July 2018 (long rain season) in a farm in Kikome, Makueni-Eastern Kenya (latitude S 02.14504°, longitude E 037. 80262°, altitude 803 m above sea level) to investigate the impact of insect pollination on yield and quality of cowpea and cucumber. Makueni County is semi-arid characterized by dense bushes and shrubs and wild trees such as *Acacia tortilis, Terminalia brownie,* and *Balanites aegyptiaca* (Makueni County Development Plan, 2017). Soils in this region are usually sandy characterized by a pH range of 5.1 to 7.2 and low to moderate organic matter content (0.43%-1.87% TOC). The area experiences a bimodal type of rainfall with short rains in November/December and long rains in March/April. Rainfall is usually lower than 250 mm annually while the average temperature is 22ºC annually. The temperature range and rainfall pattern coupled with the irrigation water from Athi River can support cowpea and cucumber cultivation in the farms.

During both seasons, cowpea variety Ken Kunde and cucumber variety Ashley that was purchased from an agrochemical store in Nairobi were used. Conditions at the experimental site were as follows: Soil pH: 7.4 Ec: 0.08-0.13mS/cm, N: 0.03%; available P: 114mg/kg; available K: 0.3me1/100g, CEC: 12meq/100g, soil moisture content: 2.7%.

Treatments and Experimental Layout

Experiments were laid out as a split plot in a randomized complete block design with three replicates. Main plots comprised of bagging treatments at two levels; one bagged with an insect proof net (size 0.6mm bought from Smaat enterprises Nairobi) and the other was left unbagged. A 1m empty lane was left between the main plots. Sub-plots consisted of two plant species *viz*. cowpea variety Ken Kunde and cucumber variety Ashley. Subplots measured 10 m x 7 m with a 1m distance between them and an inter- and intra-row spacing of 3 0 cm x 25 cm and 90 cm x 30 cm in cowpea and cucumber respectively.

Crop Establishment

To establish the plants, two seeds were directly sown in planting holes at depth of 2.5cm in the field. DAP fertilizer was incorporated into the soil while planting cucumber, while no fertilizer was used in cowpea plots. Two weeks after germination, the seedlings were thinned to one seed per planting hole while gapping was done where seeds failed to germinate. Plants were watered once per week by feeling the soil and irrigating when the topsoil was dry but before it dried to a greater depth. In addition, weeding was done two times during the cropping cycle. CAN fertilizer at the rate of 100 kg/ha was applied in cucumber for top dressing to stimulate vegetative growth.

Insect Pollinators' Diversity and Abundance Assessment

Cowpea and cucumber plants started flowerings 35 and 45 days after planting respectively. Thus, assessment of insect pollinators commenced when 50% of the crops had flowered until the end of the blooming period. Data on insect pollinators of respective crops were collected on four days interval: four days on cowpea plots, then the next four days on cucumber. For cowpea, observations were done from 7:00am-10:00 am since its flowers have been reported to open between 6:00 am and 6:30 am and close between 11:30 am and 12:00noon (Ige *et al*., 2011). Observations in cucumber were however done from 7:00 am to 5:00 pm since its flowers have been reported to open at 5:30 am and close between 6:30 pm and 6:00 am (Khaja Rubina, 2010).

Insect pollinators of respective unbagged plants were recorded and samples collected using a usual cone-shaped sweep net and stored in vials containing 70% ethanol. Preserved insects were transported to a laboratory at the Zoology Department in the National Museums of Kenya, Nairobi for identification. The abundance and diversity of respective insect pollinators were thereafter determined.

Crop Yield Analysis

Cowpea pods and cucumber fruits were harvested at physiological maturity when cowpea pods were dry and cucumber fruits fully mature but partially ripe shown by appearance of yellow colour (Kader, 1995).Yield was determined by counting the number of cowpea pods and cucumber fruits per plant. The weight, length and diameter of cowpea pods and cucumber fruits was measured before the seeds were extracted. The number and the weight of the seeds was recorded from each cowpea pod and cucumber fruit after measuring using a scale balance (model MA 40). The germination percentage of the test crop seeds was determined using procedures obtained from International Seed Testing Standards (2015). The surface of the container was sterilized by wiping with 70% ethanol. The Petri dishes and their covers were labelled taking note of the number of replicate, date and the crop variety. 10% agar solution was prepared by dissolving 10g of agar powder in 100ml of warm distilled water heated on a hot plate. The solution was allowed to boil to completely dissolve all the agar, slightly cooled to 50^{o}C then poured into labelled petri dishes. 100 seeds of both cowpea and cucumber were used for the germination test. The seeds were arranged equidistantly in the petri dishes on the surface of the agar in four replicates for cucumber and five replicates for cowpea. The petri dishes were covered with their lids then placed in an incubator at room temperature. The scores for germination were taken when the radicles were 2mm long. Germination percentage was recorded after every 24hours for 14days as the percentage of the total seeds that germinated out of total seeds sowed.

Statistical Analysis
The frequency of visitation by each insect pollinator was recorded to identify the most abundant on cowpea and cucumber flowers and influencing their yield and quality using the equation as reported by Preston (1948):

$$\text{Relative abundance of species} = \frac{Number\ of\ individual\ visits\ on\ flowers}{Total\ number\ of\ pollinators} X100$$

Pollinator count data was used to compute the Shannon Weiner index (Claude & Nobert, 1949) of diversity using the formulae:

$$H = \sum[(\mathrm{Pi}) \times \ln(\mathrm{pi})],$$

Where pi is the proportion of the i^{th} species of the pollinators.

Statistical differences in mean number of insect pollinators of respective crops was assessed through analysis of variance (one-way ANOVA) using GENSTAT version 4 while the means were separated using Dancun's multiple range test at $\alpha = 0.05$.

To assess the impact of insect pollinators of cowpea and cucumber, data obtained on number of pods/fruits/plant, pod/fruit shape, pod/fruit weight, pod/fruit length, pod/fruit width, number of seeds per pod/fruit, seed weight, germination percentages as the dependent variables and pollination treatments (bagged, and unbagged) as independent variables was analysed using descriptive statistics. The data was analysed for each of the variable categorized based on treatment type (bagged or unbagged), seasons (first and second) and crop type (cowpea and cucumber). The quantitative data for each crop was analysed for inferential statistics using an independent samples t-Test at 95% confidence interval to test for significant differences between the different categories of the independent variable that was inclusive of seasonal variation and treatments.

Results and Discussion

Diversity and Abundance of Insect Pollinators of Cowpea and Cucumber

While 8 insect pollinator species were observed and recorded on cowpea flowers, 12 were recorded in cucumber flowers during the short and long rain seasons (Table 1). Of these, *A. mellifera* was the most abundant during the two growing seasons in both crops. Whereas 75% of the insect pollinator species recorded in cowpea belonged to the order Hymenoptera, only 33% belonged to the order Hemiptera, the most abundant, in cucumber during the short and long rain seasons (Table 1). A higher diversity of insect pollinator species was found during the long rain seasons (cowpea = 1.53; cucumber = 1.21), relative to the short rain seasons (cowpea =0.18; cucumber =0.16) (Table 1). In cowpea, *A. mellifera* foraged mainly at 9:00am-10:00 am and 7:00am-8:00 am during the short and long rain seasons respectively (Figure 1). However, in cucumber, the same species foraged more between 9:00 am to 10:00 am and 8:00am-9:00 am during the season I and II respectively (Figure 2). Except for the purposes of identification, all individuals rather than *A. mellifera* were treated as a single population (non-*Apis* species). In cowpea, the activity of non-*Apis* species peaked between 8:00 am- 9:00 am during both seasons. In cucumber, the peak activity of non-*Apis* species was recorded between 7:00 am and 8:00 am .and 8:00 am and 9:00 am during the short and long rain seasons respectively.

The aim of the present study was to document the diversity, abundance, and contribution of important insect pollinators of cowpea and cucumber as important crops in Makueni, an ASAL. These results are important in identifying important and efficient insect pollinators for enhanced crop yield. Both *Apis* and non-*Apis* species have key roles in enhancing the productivity of cowpea and cucumber. From the results, it is clear that the *A.mellifera* was the most important in the yield and quality of the test crops as it was the most abundant during the two cropping seasons (97.58% and 85.35% in cowpea and 98.43% and 68.28% in cucumber in season I and II respectively). All other insect pollinators were occasional as shown by the low abundance and infrequent visitations.

Effects of Insect Pollinators on the Yield and Quality of Cowpea and Cucumber.

During the two seasons, cowpea and cucumber plants that were bagged had significantly higher number of crooked pods and fruits than the unbagged plants (P <0.001). Bagged cowpea pods and cucumber fruits were of a lower weight significantly different from the unbagged plots (p<0.001). In addition, the number and the weight of the seeds were significantly lower in bagged plots than the unbagged plots (p<0.001). Unbagged flowers yielded wider pods and fruits than the bagged flowers and the highest germination percentage in both seasons significantly different from bagged plants (p<0.001) (Table 2 and 3). Generally, there was seasonal variation in the yield and quality of cowpea and cucumber. Both crops yielded higher during the long rain season and recorded higher quality in terms of the germination percentage (Table 2 and 3). In cucumber, an increment in yield due to insect pollination was recorded as 8.13% and 49.02% in the short and long rain season respectively. In cowpea, increment in yield due to insect pollination was recorded as 17.37% and 10.42% in the short and long rain seasons respectively.

High visitation rates of honeybees relative to other insect pollinators demonstrates that honeybees are one of the most reliable insect pollinators within the study area. This is in agreement with other studies done worldwide. Kasina *et al*., (2009) observed that *A.mellifera* were the major insect pollinators of cowpea and squash (Cucurbitaceae) in Kakamega. Hordzi (2011) observed that honeybees were the main insect pollinators of cowpeas in Ghana. Ige *et al*., (2011) ranked *Apis mellifera* second most abundant insect pollinator in cowpea in Ondo State, Nigeria, and observed that the pollinator visited cowpea immediately the flowers opened. Oronje *et al*., (2012) demonstrated that *A. mellifera* were the most abundant insect pollinators of cucumber in Western Kenya. Inam *et al*., (2015) made similar observations in cucumber in Peshawar. The high abundance of *A. mellifera* is attributable to its feeding mechanism involving the engagement of several bee workers to exploit nutritional resources to the colony. Increase in population of non-bee species in the long rain season rather than *A. mellifera* was associated with an increase in yield and quality of cowpea and cucumber. Greenleaf & Kremen (2006) observed that non-Apis bees increase foraging activities of honeybees and recorded five-fold pollination efficiency of the honeybees in the presence of non-Apis bees. In another study, the non-*bee* species recorded were not efficient pollinators of sunflower (*Helianthus annuus*) but important in enhancing pollination by the honeybees (DeGrandi-Hoffman & Watkins, 2000).

Table 1. Abundance of different insect pollinators of cowpea during the two growing season

	Cowpea			Cucumber	
	Mean ± S.E per Season			Mean ± S.E per Season	
Species	Family	I	II	I	II
Apis mellifera (Hymenoptera)	Apidae	12.0 ±1.8(875)	4.5±0.7(211)	5.1±2.2(532)	3.3±0.2(454)
Mylabris merefiensis (Coleoptera)	Meloidae	2±0.2(39)	-	-	-
Ichneumonidae sp (Hymenoptera)	Ichneumonidae	-	2.4±0.3(93)	-	-
Camponotus sp (Hymenoptera)	Formicidae	-	1.7±0.1(48)	-	2.5±0.5(5)
Iphiaulax sp (Hymenoptera)	Vespidae	-	1.4±0.1(20)	-	-
Lampedes boeticus (Lepidoptera)	Lycaenidae	-	1.8±0.3(14)	-	1.5±0.1(35)
Pentatomidae sp (Hemiptera)	Pentatomidae	-	1.4±0.3(11)	-	-
Xylocopa sp (hymenoptera)	Apidae	-	1(1)	-	-
Henesepilachna reticulata (Coleoptera)	Coccinelidae	-	-	2.2±0.5(13)	-
Pelopidas mathias (Lepidoptera)	Hesperidae	-	-	1	-
Myridae sp (Hemiptera)	Myridae	-	-	-	1.8±0.1(126)
Episyrphus trisectus (Diptera)	Syrphidae	-	-	-	1.4±0.2(27)
Lasioglossum sp (Hymenoptera)	Halictidae	-	-	-	1.3±0.10(24)
Dysdercus cardinalis (Hemiptera)	Pyrrhocoridae	-	-	-	1.5±0.14(21)
Carpophilus ligneus (Hemiptera)	Nitidulidae	-	-	-	1.7±0.4(8)
Reduviidae sp (Hemiptera)	Reduviidae	-	-	-	1.7±0.3(5)
Dieuches sp (Hemiptera)	Lygidae	-	-	-	1

H values: Cowpea: 0.18 (Season I), 1.53(Season II). Cucumber, 0.16 (Season I) 1.21 (Season II). The values in brackets represents the total number of individual insect pollinators observed on respective flower

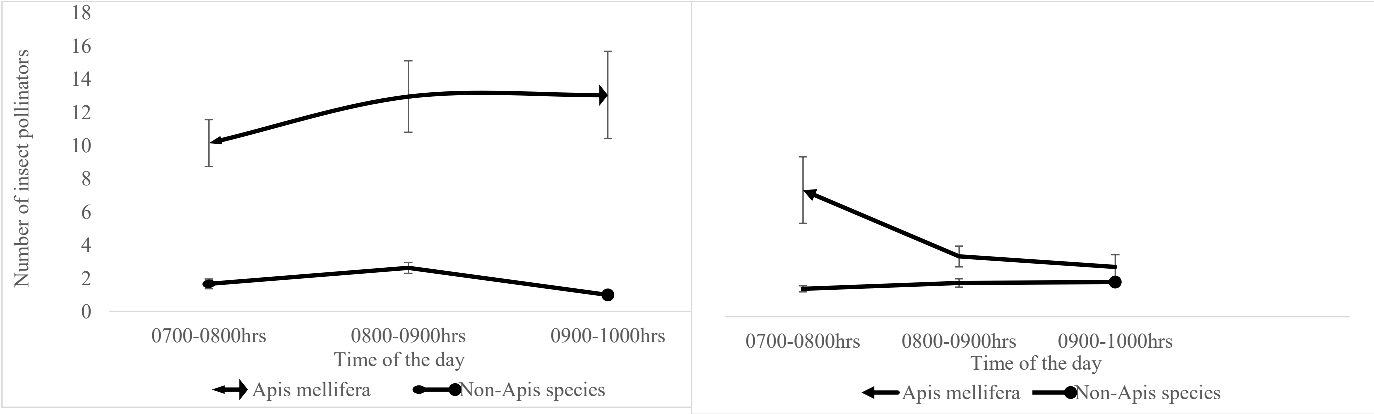

Figure 1. Changes in the mean number of insect pollinators with time of the day in cowpea during the short rain (season one) and long rain (season two)

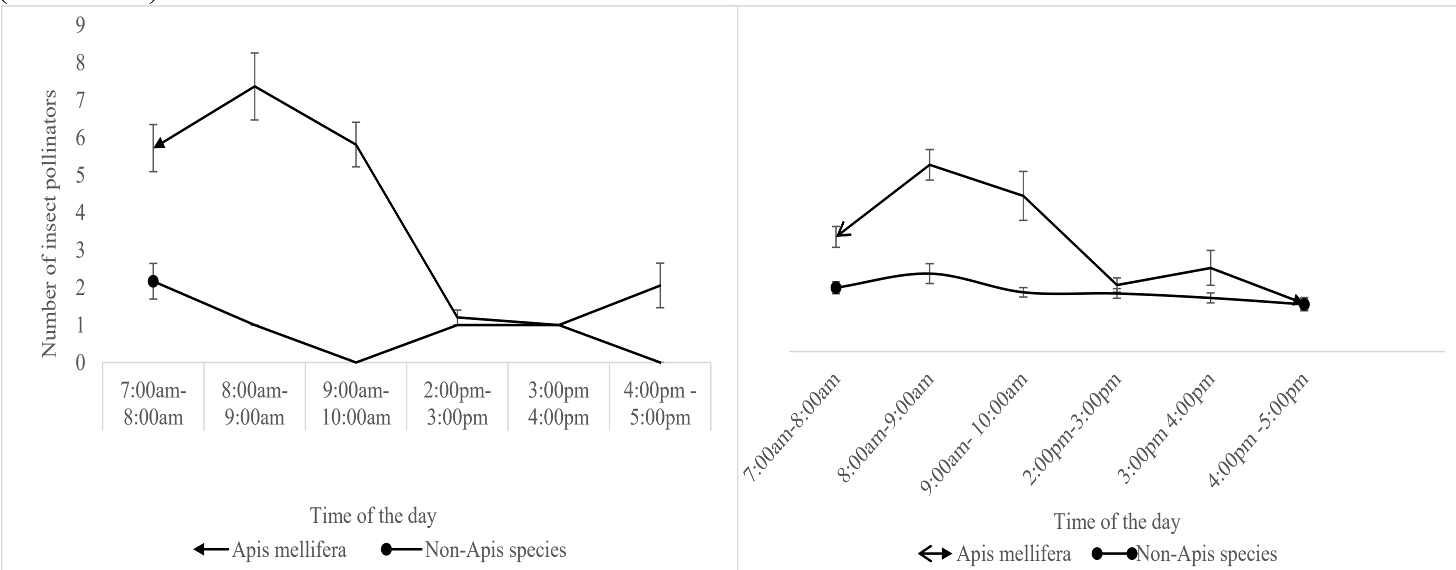

Figure 2. Changes in the mean number of insect pollinators with time of the day in cucumber during the short rain season (I) and long rain season (II).

Table 2. Mean number of cowpea yield and quality parameters during the two growing seasons in Makueni, Eastern Kenya.

	Season I				Season II			
	Treatment							
	Bagged	Unbagged			Bagged	Unbagged		
Parameters	Mean±S.E.		T	P	Mean±S.E.		T	P
Total pods/plant	7.53±0.52	9.11±0.31	-2.59	0.012	7.64±0.38	8.53±0.48	-1.44	0.154
Crooked pods/plant	5.25±0.31	0.56±0.12	13.9	< 0.001	3.94±0.25	0.25±0.09	13.93	< 0.001
Average pod weight(g)	3.08±0.1	3.87±0.19	-3.74	< 0.001	2.091±0.07	4.002±_0.22	-1.62	< 0.001
Pod length(cm)	12.99±0.11	14.82±0.13	-10.7	< 0.001	12.07±0.16	14.59±0.17	-10.6	< 0.001
Pod diameter(cm)	2.486±0.06	2.678±0.08	-5.12	< 0.001	2.38±0.03	2.96±0.03	-15	< 0.001
Number of seeds per pod	12.75±0.27	14.97±0.16	-7.15	< 0.001	11.61±0.24	15.78±0.34	-9.91	< 0.001
Seed weight(g)	2.50±0.11	3.52±0.08	-7.47	< 0.001	1.67±0.04	3.5±0.18	-9.83	< 0.001
Germination %	76.28±1.87	91.61±1.29	-6.75	< 0.001	79.19±1.26	99.86±1.10	-16.4	< 0.001

Table 3. Mean number of cucumber yield and quality parameters during the two growing seasons in Makueni, Eastern Kenya.

	Season one				Season two			
	Treatment				TREATMENT			
	Bagged	Unbagged			Bagged	Unbagged		
Parameters	Mean±S.E.		T	P	Mean±S.E.		T	P
Total fruits/plant	6.83±0.4	9.03±0.25	-4.64	< 0.001	5.75±0.34	11.72±0.58	-8.94	< 0.001
Crooked fruits/plant	5.5±0.37	0.78±0.16	11.59	< 0.001	4.22±0.41	0.14±0.07	9.85	< 0.001
Average fruit weight)kg)	0.25±0.01	0.43±0.04	-4.29	< 0.001	0.27±0.06	0.71±0.03	-6.17	< 0.001
Average length (cm)	19.55±0.38	22.01±0.45	-4.23	< 0.001	18.64±1.04	25.23±0.24	-6.15	< 0.001
Fruit diameter(cm)	15.11±0.2	18.74±0.45	-7.42	< 0.001	15.43±0.74	21.36±0.20	-7.75	< 0.001
Number of seeds /fruit	78.6±15.28	350.4±11.77	-14.09	< 0.001	19.8±4.2	552.2±34.13	-15.48	< 0.001
Seeds weight	0.62±0.12	4.5±0.15	-20.74	< 0.001	0.27±0.06	6.78±0.21	-29.52	< 0.001
Germination %	0.28±1.19	82.25±2.6	-31.48	< 0.001	0.75±0.42	88.39±2.26	-38.16	< 0.001

In cowpea, the peak foraging activity of insect pollinators was between 8:00am-9:00 am and 7:00am-8:00am in short and long rain seasons respectively. Studies elsewhere contradict with this study. In Cameroon, Fohouo *et al*., (2009) recorded the peak foraging activity of honeybee on cowpea between 7:00am-8:00am, In Peshawar, the activity of *Apis mellifera* on *Pisum sativum* (Fabaceae) flowers peaked in the morning hours between 9:00am-12:00pm and was lowest in the evening hours between 3:00pm-5:30pm (Naeem *et al*., 2018). In pigeon pea (Fabaceae), Prashanth (2009) in Bangalore recorded the overall activity of insect pollinators in the morning, afternoon and evening as 15.74%, 33.87% and 50.82% respectively. The present study recorded the peak activity of *Apis mellifera* in cucumber between 9:00am to 10:00am and 8:00am-9:00am during the short and long rain seasons respectively. Other studies have reported on the peak activity time of cucumber. Nepi *et al*., (1996) in Italy recorded the peak activity of honeybee in *Cucurbita pepo* (Cucurbitaceae) between 7:00 am-9:00 am. Similarly, Thakur (2007) recorded peak activity of honeybees on cucumber in Nauni, Solan, between 9:00 am-10:00 am. In Peshawar, Inam *et al.,* (2005) recorded the peak activity of honeybees in cucumber in the evening (1.03bees/plot), and the lowest population in the afternoon (0.78bees/plot). Dorjay *et al.,* (2017) in Jammu observed and recorded that the population of *Apis mellifera* on cucumber flowers peaked during 9:00 am-10:00 am. Though not measured in the present study, differences in the peak activity of *Apis mellifera* on the test crops from other studies could be due to changes in temperature and humidity, which influences the activity of insect pollinators (Bhattacharya, 2017).

Yield results from this study indicate that the yield recorded in the unbagged plots were higher and significantly different from bagged treatments. This is attributed to the role of insect pollinators, notably *Apis mellifera*, in yield and quality improvement of the test crops. It was however noted that fruit set occurred inside bagged plots of the test crops. In cowpea, self-pollination is likely to have taken place leading to pod set, but the yield was considerably lower than that recorded in unbagged plots. This is possible due to wind and self-pollination. The number of pods per plant, pod weight, pod length and width, number of seeds per pod, seed weight per pod, and germination percentage in cowpea were all highest in unbagged plots and significantly different from the bagged plots. These studies agree with other work reported worldwide. In Western Kenya, cowpea yield from bagged and unbagged treatments per year was 0.78 kg and 1.33kg respectively recording 45.05 US$ income (Kasina *et al*., 2007). In pigeon pea (Fabaceae), Prashanth (2009) recorded a significant difference between caged and uncaged plots in the number of pods per plant (92.25%), pod weight (43.52%), total seeds (26.04%) and seed weight per pod (51.06%) ($p<0.05$). He further recorded germination percentage as 90% and 82% in uncaged and caged plots respectively though there was no significant difference between the treatments. In Tizi-Ouzou area (Algeria), Aouar-Sadli *et al*., (2008) recorded that the length, and number of seeds per pod of broad bean (Fabaceae), were more in uncaged than caged plots. In Constaine region (Algeria) Benachour *et al*., (2007) recorded a higher fruit set in cross-pollinated broad bean significantly different from self-pollination.

Likewise, fruit set occurred in both bagged and unbagged plots of cucumber. The unbagged plots, however, recorded higher yield and quality when compared to the bagged plots. The difference in yield is attributed to frequent visitation by insect pollinators in unbagged plots where there was open access to all kinds of insect pollinators, unlike bagged plots where the insect pollinators were excluded. This is in agreement with previous studies such as Shah *et al.,* (2015) who recorded fruit set in bagged plots of cucumber and attributed it to chances of wind pollination. It, however, contradicts with studies done by Oronje *et al*., (2012) who observed that all caged karela (Cucurbitaceae) flowers aborted without setting fruits. Fruit set in bagged cucumber could be attributed to chances of wind pollination (Kasina *et al*., 2007: Shah *et al*., 2015). The present study recommends that measures to augment and conserve insect pollinators should be taken to enhance the yield and quality of cowpea and cucumber in the study area. Good agricultural practices such as integrated pollinators and pest management are recommended to conserve biodiversity of insect pollinators. Trap nests could also be introduced in areas where bees could emerge.

Conclusion

This study highlights the positive contribution of insect pollinators to yield and quality improvement of cowpea and cucumber. Differences in yield and quality of pollinated and non-pollinated test crops is attributed to the role of insect pollinators since insect pollinators were not augmented. There is however a need to manage insect pollinators for improved performance of the test crops. This can be achieved by adoption of good agricultural practices notably avoidance of indiscriminate use of pesticides and management of farm surrounding habitats to conserve insect pollinators. Moreover, studies on the role of environmental factors as temperature and humidity on the insect pollinators' activities are recommendable as their behaviour may vary with environmental changes.

Acknowledgments

The present study was funded by Bayer Germany and the National Museums of Kenya. I am grateful for the financial support. I am much grateful to Dr. Esther Kioko (National Museums of Kenya) and Dr. Lucy K. Murungi (JKUAT) who have tirelessly guided me during the research period. Special thanks to all friends and colleagues that offered me support during my research.

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